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RESEARCH MEMORANDUM

EFFECT OF TAPER RATIO ON LIFT, DRAG, AND PITCHING-
MOMENT CHARACTERISTICS OF THIN WINGS OF
ASPECT RATIO 3 WITH 53.1° SWEEPBACK
OF LEADING EDGE AT SUBSONIC AND
SUPERSONIC SPEEDS

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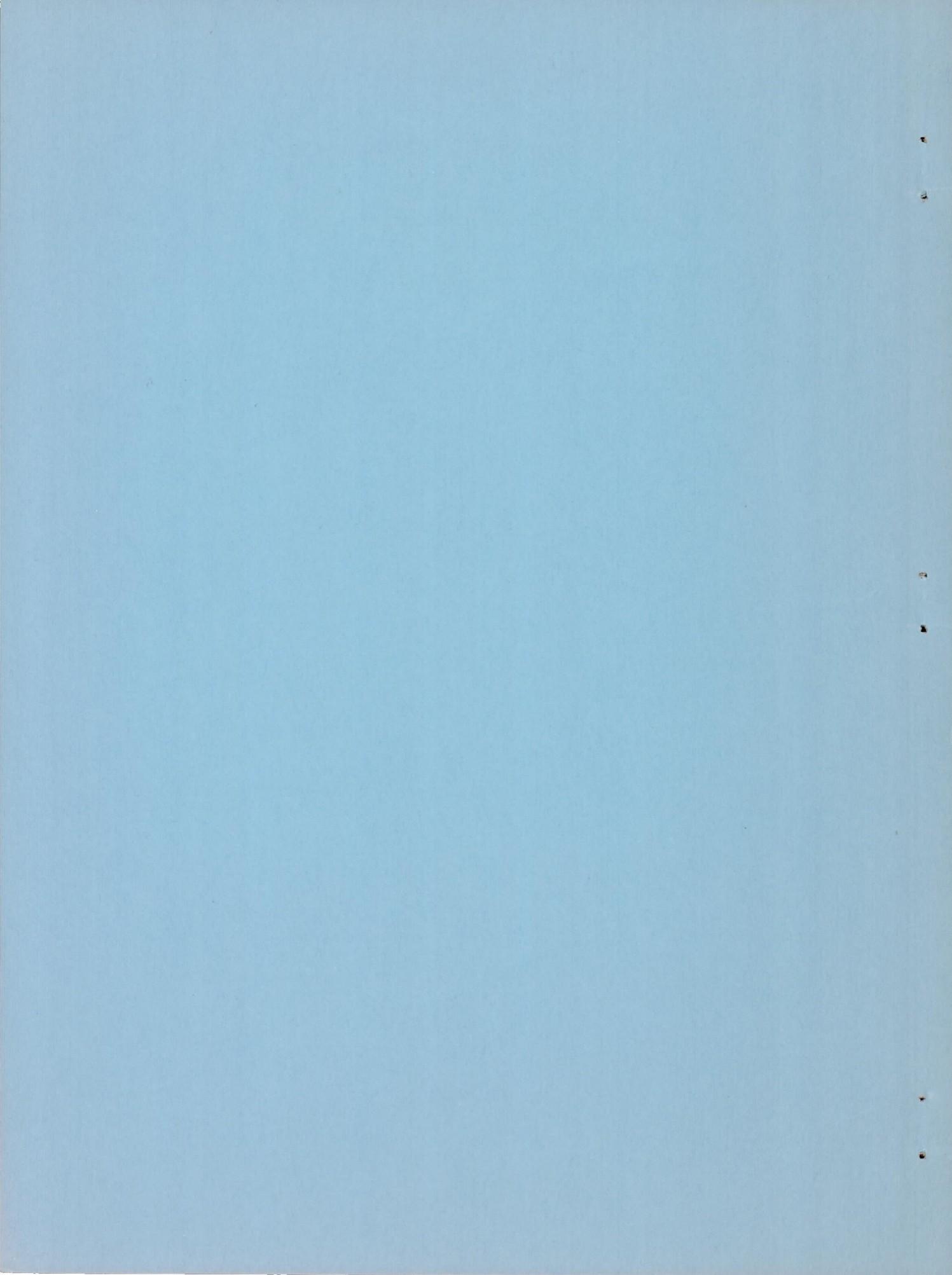EFFECTIVE DATE: AUGUST 16, 1957

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SUPERSONIC SPEEDS

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SUMMARY

The results of a wind-tunnel investigation are presented which
show the effect of the variation of taper ratio on the lift, drag, and
pitching-moment characteristics of thin wings of aspect ratio 3 with
53.1° sweepback of the leading edge. Three wings, with taper ratios of
0, 0.2, and 0.4, in combination with a high-fineness-ratio body were
studied in the investigation.

Measurements of the forces and moments on the wing-body combina-
tions were obtained throughout an angle-of-attack range from -4° to a
maximum of +17° at Mach numbers of 0.6 to 0.9 and 1.2 to 1.9. All
models were tested at a Reynolds number of 3.0 million per foot at all
Mach numbers. (This corresponds to Reynolds numbers varying from 2.9
to 3.6 million when based on the mean aerodynamic chords of the models.)
In addition, the models were tested at Reynolds numbers of 4.0 million
per foot at all subsonic Mach numbers and 6.0 million per foot at Mach
numbers of 0.8 and 0.9.

Static longitudinal stability at subsonic speeds was reduced near
a lift coefficient of 0.5 for the wings with taper ratios of 0.2 and
0.4. Variation of taper ratio did not affect the minimum drag coeffi-
cient at subsonic speeds. At supersonic speeds increasing the taper
ratio resulted in a slight reduction in the minimum drag coefficient.
Drag due to lift was decreased at all Mach numbers by an increase in
taper ratio from 0 to 0.2.

INTRODUCTION

As part of the continuing investigation of low-aspect-ratio wings by the NACA, the effects of taper ratio on the aerodynamic characteristics of swept wings of aspect ratio 3 at subsonic and supersonic speeds have been investigated in the Ames 6- by 6-foot supersonic wind tunnel. This report is devoted to the presentation and discussion of the results obtained during this study.

NOTATION

b wing span

$\bar{c}$ mean aerodynamic chord, $\dfrac{\int_0^{b/2} c^2\,dy}{\int_0^{b/2} c\,dy}$

c local chord

C_D drag coefficient, $\dfrac{\text{drag}}{qS}$

C_L lift coefficient, $\dfrac{\text{lift}}{qS}$

C_m pitching-moment coefficient, measured about the quarter point of the mean aerodynamic chord, $\dfrac{\text{pitching moment}}{qS\bar{c}}$

$\dfrac{L}{D}$ lift-drag ratio

M free-stream Mach number

q free-stream dynamic pressure

R Reynolds number

S wing area, including area formed by extending the leading and trailing edges to the plane of symmetry

y distance perpendicular to plane of symmetry

α angle of attack of body axis, deg

λ taper ratio, the ratio of the chord at the tip to the chord at the plane of symmetry

APPARATUS AND MODELS

The investigation was performed in the Ames 6- by 6-foot supersonic wind tunnel. This wind tunnel, which is fully described in reference 1, has a closed section and is of the variable-pressure type. It can be operated at Mach numbers varying from 0.6 to 0.9 and from 1.2 to 1.9. Model wing-body combinations are sting-mounted in the wind tunnel, and the aerodynamic forces on the models are measured with an internal electrical strain-gage balance. A typical model installation is shown in figure 1.

Three wing-body combinations were used during the investigation. Sketches of the models are presented in figure 2. All of the wings were of aspect ratio 3 and had 53.1° sweepback of the leading edge. All had an NACA 0003-63 airfoil section in a streamwise plane and had the same plan-form area. The taper ratios of the wings were varied from 0 (a triangular wing) to 0.4. All of the wings were tested in combination with the same circular body. The equation of the body is included on figure 2. The wing panels were constructed of steel, painted, and hand-sanded to a smooth finish. The smooth finish was maintained throughout the tests.

TESTS AND PROCEDURES

Range of Test Variables

Lift, drag, and pitching moment were measured throughout an angle-of-attack range varying from -4° to a maximum of +17° at Mach numbers of 0.6 to 0.9 and 1.2 to 1.9. All models were tested at a Reynolds number of 3.0 million per foot at all Mach numbers. In addition they were tested at Reynolds numbers of 4.0 million per foot at all subsonic Mach numbers and 6.0 million per foot at Mach numbers of 0.8 and 0.9. The following table presents the corresponding Reynolds numbers based on the mean aerodynamic chord.

$R \times 10^{-6}$, per ft	$R \times 10^{-6}$, based on mean aerodynamic chord		
	$\lambda = 0$	$\lambda = 0.2$	$\lambda = 0.4$
3.0	3.6	3.1	2.9
4.0	4.8	4.1	3.8
6.0	7.2	6.2	5.7

Reduction of Data

Data presented in this report have been reduced to NACA coefficient form. The pitching moment has been referred to the quarter point of the mean aerodynamic chord. The data have been corrected to account for the differences known to exist between measurements made in the wind tunnel and in a free stream. The corrections applied account for the following factors:

1. The increase in airspeed in the vicinity of the model at subsonic speed as a result of constriction of the air stream by the walls of the wind tunnel.

2. The change in angle of attack of the model induced by the walls of the wind tunnel at subsonic speeds as a consequence of lift on the model. The corrections to the data amounted to:

$$\Delta \alpha = 0.554 \; C_L, \; \text{deg}$$

$$\Delta C_D = 0.0097 \; C_L^2$$

$$\Delta C_m = 0$$

3. The inclination of the air stream in the wind tunnel. These corrections were of the order of $-0.13°$ and $-0.10°$ at subsonic and supersonic speeds, respectively.

4. The effect on the drag measurements due to the longitudinal variation of static pressure in the test section.

5. The effect on the drag measurements caused by mounting the models on a sting. The base pressure was measured and the drag data adjusted to correspond to a base pressure equal to the static pressure of the free stream.

RESULTS AND DISCUSSION

Lift, drag, and pitching-moment coefficients are presented in tables I, II, and III for the wings with taper ratios of 0, 0.2, and 0.4, respectively. The tabulations include data for all test conditions. For the purpose of analysis, only a portion of these data is presented in graphical form. The largest part of the discussion is devoted to the results obtained at a Reynolds number of 3.0 million per foot, since that was the highest Reynolds number at which data could be obtained throughout the entire Mach number range. It will be shown, however, that the conclusions

drawn from results obtained at that Reynolds number also apply at a
Reynolds number of 6.0 million per foot at Mach numbers of 0.8 and 0.9.

Lift

The effect of taper ratio on the variation of the lift coefficient
with angle of attack is shown in figure 3. Increasing the taper ratio
from 0 to 0.4 had only small effect on the lift-curve slope at zero lift.
At angle of attack, however, variation of taper ratio resulted in large
differences in the lift coefficients obtained at subsonic speeds.
Increases in lift-curve slope at low to moderate angles of attack, such
as are shown in the present results, particularly for the wings with
taper ratios of 0.2 and 0.4, have been shown by previous tests of low-
aspect-ratio wings with thin airfoil sections (e.g., refs. 2 and 3) to
be concomitant with flow separation near the leading edge. Although
such flow separation results in a reduction in the leading-edge pressures,
it generally increases the lifting pressures over the rearward portions.
The chordwise extent of the effect of separation generally increases with
increasing spanwise distance from the plane of symmetry. For the wings
of the present investigation the increases in lift-curve slope at moderate
angles of attack generally were reduced as Reynolds number was increased,
as will be shown in the portion of the discussion devoted to the effect
of Reynolds number. Examination of the lift and moment data at the higher
angles of attack indicated that stalled flow must have occurred at the
tip sections and that unusually high loading occurred on the inboard
sections.

Pitching Moment

The effect of taper ratio on the variation of pitching-moment
coefficient with lift coefficient is presented in figure 4. Increas-
ing the taper ratio caused a deterioration of the static longitudinal
stability at subsonic speeds, as indicated by the nonlinear variations
of the pitching-moment coefficient with lift coefficient for the wings
with taper ratios of 0.2 and 0.4. The increased static longitudinal
stability for these wings in the low lift-coefficient range, correspond-
ing to the range in which the lift-curve slope increased with increasing
angle of attack, offers additional indication of the probable occurrence
of leading-edge flow separation.

Of considerably more importance, however, was the reduction of the
static longitudinal stability of the wings with taper ratios of 0.2 and
0.4 near a lift coefficient of 0.5 at subsonic speeds. As indicated
previously, this reduction of the longitudinal stability must have resulted
from stalled flow at the tip sections. The degree of instability increased

with increasing taper ratio. Serious pitch-up occurred for the wing with
taper ratio 0.4 at a Mach number of 0.6 when the moment center was located
at the quarter point of the mean aerodynamic chord. At supersonic speeds
the variation of the pitching-moment coefficient with lift coefficient for
the wings with taper ratios of 0.2 and 0.4 also showed a decrease in static
longitudinal stability at the higher lift coefficients. This decrease was
measured for the wing with taper ratio of 0.4 even at a Mach number of 1.9.

Nonlinear variations of the pitching-moment coefficient with lift
coefficient, similar to those obtained for the wing with taper ratio of
0.2, can be minimized by locating a horizontal tail in a position which
takes advantage of the characteristics of the flow field behind the wing
(see ref. 4). It is unlikely, however, that an acceptable variation of
pitching-moment coefficient with lift coefficient can be obtained for an
aircraft utilizing the wing with taper ratio 0.4 without some modification
of the wing to delay stalling of the wing tips.

Drag

The effect of taper ratio on the variation with lift coefficient of
the drag coefficient is shown in figure 5. Increasing the taper ratio
from 0 to 0.2 resulted in a reduction of the drag coefficients measured
at moderate to high lift coefficients and had only small effect on the
minimum drag. These effects have been summarized in figure 6, in which
the variation of drag coefficient with Mach number has been presented
for various lift coefficients. Increasing the taper ratio to 0.4 resulted
in no significant reductions of the drag coefficient. The latter result
is in agreement with the results obtained during an investigation of
swept wings with taper ratios varying from 0.3 to 1.0 (ref. 5). Results
presented in the referenced report showed that at high subsonic speeds
the drag due to lift was only slightly decreased by increasing taper
ratio beyond 0.3.

As a result of the reduction of drag due to lift when taper ratio
was increased, the lift-drag ratios of the wings with taper ratios of
0.2 and 0.4 were generally higher than the ratios for the wing with
taper ratio of 0 at both subsonic and supersonic speeds, as shown in
figure 7. At subsonic speeds the highest lift-drag ratios were obtained
for the wing with taper ratio of 0.2. The maximum lift-drag ratios
measured at supersonic speeds were those for the wing with taper ratio
of 0.4. These maximums were, however, only slightly higher than those
for the wing with taper ratio of 0.2.

In recapitulation, increasing the taper ratio from 0 to 0.2 resulted
in a significant improvement of the drag characteristics. Since increas-
ing the taper ratio to 0.4 generally did not result in further significant
improvement but led to severe pitch-up, it appears that the optimum taper
ratio is about 0.2.

Effect of Reynolds Number

The effect of variation of Reynolds number on the lift, drag, and pitching-moment coefficients at high subsonic speeds is illustrated in figure 8, in which results obtained at a Mach number of 0.8 are presented. Increasing the Reynolds number from 3.0 to 6.0 million per foot alleviated the effect of leading-edge separation on the lift and pitching-moment characteristics of the wings with taper ratios of 0.2 and 0.4. At a Reynolds number of 6.0 million per foot, the lift curves were linear over a wider range of angles of attack, and the increases in static longitudinal stability at low lift coefficients were smaller than at a Reynolds number of 3.0 million per foot. Because of structural limitations of the models, tests at the highest Reynolds number were not conducted in the range of lift coefficients in which reduced stability occurred for the wings with taper ratios of 0.2 and 0.4.

Since the effect of taper ratio on the variation of the drag coefficient with lift coefficient was shown to be significant at a Reynolds number of 3.0 million per foot, figure 9 has been included to show the variation with Reynolds number of the drag coefficients at various lift coefficients for Mach numbers of 0.8 and 0.9. Comparison of the results for the three wings indicates that increasing the Reynolds number did not affect materially the reductions in drag coefficient obtained as a result of increasing taper ratio.

CONCLUDING REMARKS

A wind-tunnel investigation has been conducted in order to determine the effect of varying the taper ratio on the lift, drag, and pitching-moment characteristics of thin wings of aspect ratio 3 and with 53.1° sweepback of the leading edge. Three wings, with taper ratios of 0, 0.2, and 0.4, were tested.

All wings showed the effect at subsonic speeds of flow separation at the wing tips; the effects of separated flow were shown to increase with increasing taper ratio. The static longitudinal stability at subsonic speeds was reduced near a lift coefficient of 0.5 for the wings with taper ratios of 0.2 and 0.4. Although the most satisfactory variation of pitching-moment coefficient with lift coefficient was obtained for the triangular wing, used to investigate a taper ratio of 0, the degree of instability for the wing with taper ratio of 0.2 was much less severe than that for the wing with taper ratio of 0.4.

Variation of taper ratio did not affect the minimum drag coefficient at subsonic speeds, while at supersonic speeds an increase in taper ratio resulted in a slight reduction in the minimum drag coefficient. Drag due to lift was decreased at all Mach numbers by an increase in taper ratio from 0 to 0.2.

Ames Aeronautical Laboratory
    National Advisory Committee for Aeronautics
        Moffett Field, Calif., Oct. 20, 1954.

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TABLE I.- AERODYNAMIC CHARACTERISTICS OF TRIANGULAR WING
(a) R = 3.0 million per foot

| M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.60	-0.41	-0.022	0.0067	0.003	0.80	12.94	0.743	0.1713	-0.080	1.50	-2.17	-0.113	0.0163	0.028
	-.68	-.037	.0073	.005		15.06	.823	.2217	-.093		-3.23	-.168	.0215	.042
	-1.22	-.065	.0082	.008		17.11	.913	.2811	-.109		-4.27	-.220	.0280	.055
	-2.31	-.127	.0109	.015		18.15	.941	.3097	-.118		.09	.005	.0115	-.001
	-3.38	-.191	.0158	.022							.36	.022	.0117	-.005
	-4.47	-.253	.0230	.028	0.90	-.36	-.027	.0065	.005		.90	.051	.0122	-.012
	.05	0	.0066	.001		-.63	-.041	.0069	.007		1.96	.104	.0155	-.026
	.33	.020	.0067	-.002		-1.19	-.076	.0080	.012		3.01	.158	.0207	-.039
	.87	.050	.0076	-.005		-2.30	-.153	.0120	.025		4.07	.211	.0271	-.052
	1.96	.111	.0101	-.012		-3.41	-.230	.0187	.036		6.17	.312	.0447	-.076
	3.04	.173	.0145	-.019		-4.51	-.305	.0281	.046		8.27	.413	.0698	-.100
	4.11	.234	.0213	-.025		.05	.002	.0062	.001		10.37	.508	.1011	-.124
	6.34	.361	.0428	-.034		.35	.027	.0065	-.002		12.46	.600	.1390	-.146
	8.48	.477	.0717	-.039		.91	.063	.0076	-.008		14.56	.681	.1816	-.163
	10.63	.591	.1106	-.047		2.02	.138	.0109	-.020		15.61	.721	.2054	-.170
	12.77	.704	.1588	-.054		3.13	.212	.0170	-.031					
	14.90	.804	.2129	-.062		4.24	.291	.0261	-.042	1.70	-.30	-.015	.0113	.004
	17.01	.884	.2683	-.069		6.44	.431	.0524	-.058		-.57	-.027	.0116	.007
	18.06	.921	.2975	-.073		8.63	.561	.0887	-.074		-1.10	-.051	.0126	.013
											-2.16	-.099	.0158	.024
0.70	-.42	-.022	.0067	.004	1.20	-.34	-.021	.0107	.005		-3.21	-.147	.0203	.035
	-.69	-.037	.0072	.005		-.61	-.037	.0111	.010		-4.25	-.193	.0261	.046
	-1.17	-.068	.0080	.009		-1.15	-.070	.0122	.018		.08	.004	.0113	-.001
	-2.26	-.132	.0111	.017		-2.22	-.141	.0159	.036		.36	.019	.0113	-.005
	-3.34	-.196	.0161	.024		-3.28	-.212	.0217	.054		.90	.045	.0123	-.011
	-4.42	-.263	.0239	.031		-4.36	-.298	.0311	.073		1.95	.092	.0150	-.022
	.05	0	.0064	.001		.06	.004	.0106	-.001		3.00	.140	.0194	-.034
	.33	.022	.0068	-.002		.34	.027	.0106	-.006		4.04	.185	.0251	-.044
	.88	.052	.0077	-.005		.88	.062	.0117	-.015		6.13	.273	.0406	-.065
	1.98	.117	.0105	-.014		1.94	.128	.0152	-.031		8.22	.361	.0623	-.086
	3.06	.182	.0153	-.021		3.01	.198	.0207	-.049		10.31	.446	.0901	-.106
	4.15	.246	.0224	-.028		4.06	.267	.0283	-.066		12.40	.527	.1236	-.126
	6.39	.374	.0448	-.038		6.20	.405	.0510	-.100		14.49	.605	.1624	-.143
	8.55	.491	.0748	-.042		8.33	.541	.0838	-.133		16.58	.678	.2067	-.157
	10.71	.614	.1162	-.056							17.62	.714	.2311	-.163
	12.87	.723	.1644	-.061	1.30	-.34	-.020	.0119	.005					
	14.99	.808	.2154	-.069		-.61	-.035	.0123	.009	1.90	-.30	-.015	.0127	.003
	17.10	.891	.2726	-.081		-1.15	-.066	.0131	.017		-.57	-.026	.0129	.006
	18.14	.921	.3000	-.086		-2.21	-.127	.0168	.032		-1.10	-.047	.0135	.011
						-3.27	-.192	.0224	.048		-2.14	-.090	.0160	.021
0.80	-.34	-.023	.0066	.003		-4.33	-.256	.0299	.064		-3.19	-.134	.0199	.031
	-.63	-.038	.0069	.006		.05	.004	.0120	-.001		-4.23	-.175	.0253	.041
	-1.18	-.071	.0079	.010		.33	.024	.0122	-.005		.08	.001	.0125	0
	-2.28	-.139	.0110	.019		.88	.057	.0131	-.013		.35	.014	.0126	-.004
	-3.38	-.209	.0169	.028		1.93	.116	.0165	-.028		.88	.037	.0130	-.009
	-4.47	-.276	.0250	.036		3.00	.181	.0219	-.044		1.94	.078	.0151	-.019
	.05	.002	.0061	.001		4.06	.243	.0292	-.060		2.97	.121	.0185	-.029
	.34	.025	.0063	-.002		6.17	.362	.0493	-.089		4.02	.162	.0234	-.038
	.90	.058	.0074	-.006		8.23	.480	.0782	-.116		6.10	.240	.0368	-.057
	2.00	.125	.0104	-.016		10.40	.586	.1145	-.140		8.17	.318	.0557	-.075
	3.09	.192	.0156	-.024		12.50	.684	.1566	-.162		10.25	.396	.0807	-.092
	4.28	.260	.0234	-.032							12.33	.468	.1100	-.109
	6.37	.397	.0469	-.045	1.50	-.30	-.017	.0115	.004		14.41	.539	.1450	-.124
	8.61	.506	.0785	-.048		-.57	-.030	.0116	.008		16.50	.609	.1855	-.137
	10.79	.636	.1225	-.069		-1.11	-.058	.0123	.014		17.54	.645	.2080	-.143

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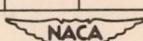
TABLE I.- AERODYNAMIC CHARACTERISTICS OF TRIANGULAR WING - Concluded
(b) R = 4.0 million per foot

M	α	C_L	C_D	C_m	M	α	C_L	C_D	C_m	M	α	C_L	C_D	C_m
0.60	-0.43	-0.025	0.0070	0.003	0.70	-3.40	-0.202	0.0166	0.024	0.80	2.10	0.130	0.0114	-0.017
	-.71	-.042	.0075	.004		-4.57	-.266	.0247	.030		3.22	.197	.0158	-.025
	-1.25	-.069	.0085	.008		.05	-.001	.0066	0		4.33	.266	.0238	-.033
	-2.35	-.131	.0114	.015		.34	.021	.0068	-.002		6.56	.405	.0484	-.046
	-3.44	-.194	.0162	.022		.90	.055	.0080	-.007		8.82	.512	.0805	-.049
	-4.53	-.255	.0232	.028		2.01	.118	.0108	-.014		11.03	.640	.1239	-.069
	.33	.019	.0068	-.005		3.11	.181	.0153	-.021		13.22	.751	.1758	-.082
	.89	.052	.0080	-.006		4.21	.249	.0226	-.028					
	1.99	.113	.0104	-.013		6.49	.377	.0454	-.039	0.90	-.36	-.021	.0069	.003
	3.07	.172	.0146	-.020		8.68	.494	.0757	-.041		-.58	-.041	.0073	.006
	4.17	.237	.0215	-.026		10.83	.609	.1171	-.055		-1.15	-.078	.0085	.012
	6.42	.365	.0436	-.036		13.06	.725	.1670	-.061		-2.28	-.152	.0119	.023
	8.60	.480	.0729	-.039		15.19	.803	.2167	-.069		-3.40	-.231	.0182	.035
	10.78	.600	.1135	-.048							-4.53	-.305	.0275	.045
	12.96	.716	.1636	-.055	0.80	-.36	-.023	.0068	.003		.14	.010	.0068	-.001
	15.11	.811	.2164	-.063		-.64	-.040	.0072	.005		.43	.029	.0071	-.004
	17.23	.892	.2736	-.070		-1.13	-.072	.0080	.010		1.02	.070	.0083	-.010
	18.30	.932	.3049	-.074		-2.24	-.138	.0110	.018		2.14	.145	.0116	-.022
						-3.35	-.205	.0162	.027		3.27	.223	.0173	-.034
0.70	-.43	-.027	.0071	.003		-4.47	-.277	.0245	.035		4.40	.297	.0264	-.043
	-.71	-.043	.0074	.005		.13	.006	.0067	-.001		6.66	.449	.0549	-.064
	-1.27	-.074	.0084	.009		.42	.025	.0068	-.003		8.89	.588	.0971	-.084
	-2.30	-.137	.0115	.017		.99	.062	.0079	-.008					

(c) R = 6.0 million per foot

| M	α	C_L	C_D	C_m	M	α	C_L	$\cdot C_D$	C_m
0.80	-0.38	-0.024	0.0071	0.003	0.90	-0.39	-0.028	0.0065	0.004
	-.68	-.044	.0075	.005		-.81	-.046	.0073	.007
	-1.18	-.077	.0085	.010		-1.21	-.084	.0084	.013
	-2.33	-.143	.0112	.019		-2.39	-.160	.0119	.025
	-3.48	-.211	.0166	.027		-3.56	-.236	.0185	.035
	-4.64	-.288	.0256	.036		-4.75	-.313	.0272	.043
	.15	.012	.0070	-.001		.16	.016	.0068	-.002
	.46	.032	.0073	-.004		.48	.037	.0072	-.005
	1.04	.065	.0081	-.008		1.01	.074	.0079	-.010
	2.18	.134	.0107	-.017		2.24	.149	.0112	-.022
	3.33	.203	.0159	-.026		3.41	.224	.0174	-.033
	4.49	.278	.0246	-.034		4.58	.299	.0266	-.041
	6.80	.411	.0496	-.046		6.97	.464	.0578	-.065
	9.12	.515	.0820	-.046					
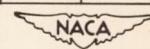
TABLE II.- AERODYNAMIC CHARACTERISTICS OF WING WITH TAPER RATIO OF 0.2
(a) R = 3.0 million per foot

| M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.6	-0.44	-0.030	0.0070	0.002	0.80	12.85	0.795	0.1805	-0.081	1.50	-2.16	-0.118	0.0164	0.032
	-.64	-.044	.0075	.004		15.01	.880	.2338	-.083		-3.22	-.174	.0216	.047
	-1.19	-.075	.0087	.008		17.10	.945	.2883	-.088		-4.26	-.230	.0282	.062
	-2.27	-.138	.0116	.014		18.18	.990	.3218	-.097		.08	.004	.0114	0
	-3.35	-.205	.0170	.023	0.90	-.39	-.032	.0062	.004		.36	.019	.0114	-.004
	-4.44	-.279	.0257	.033		-.66	-.045	.0064	.005		.89	.047	.0119	-.012
	.02	-.006	.0066	.001		-1.23	-.084	.0081	.011		1.95	.103	.0150	-.027
	.30	.016	.0068	-.001		-2.33	-.160	.0118	.023		3.00	.159	.0202	-.042
	.84	.046	.0073	-.004		-3.45	-.246	.0191	.038		4.05	.214	.0265	-.056
	1.94	.111	.0099	-.012		-4.56	-.329	.0297	.052		6.15	.322	.0440	-.085
	3.01	.175	.0137	-.020		.03	-.001	.0059	.001		8.24	.428	.0691	-.112
	4.09	.245	.0209	-.030		.32	.022	.0061	-.001		10.34	.525	.1000	-.137
	6.26	.388	.0433	-.046		.88	.057	.0070	-.006		12.43	.619	.1372	-.159
	8.43	.528	.0781	-.054		1.99	.132	.0098	-.018		14.52	.701	.1802	-.173
	10.58	.643	.1196	-.052		3.10	.214	.0154	-.032		17.01	.782	.2353	-.189
	12.73	.759	.1703	-.056		4.21	.298	.0248	-.047	1.70	-.30	-.018	.0112	.006
	14.93	.861	.2267	-.057		6.44	.465	.0536	-.072		-.57	-.030	.0114	.009
	17.04	.943	.2842	-.056		8.65	.604	.0919	-.082		-1.11	-.055	.0125	.015
	18.09	.979	.3143	-.057	1.20	-.32	-.029	.0099	.008		-2.16	-.104	.0158	.028
0.70	-.28	-.030	.0064	.003		-.59	-.044	.0104	.011		-3.20	-.151	.0205	.040
	-.55	-.044	.0069	.004		-1.13	-.078	.0117	.019		-4.25	-.200	.0265	.052
	-1.10	-.076	.0081	.008		-2.18	-.146	.0156	.037		.08	.003	.0112	0
	-2.36	-.141	.0113	.015		-3.24	-.219	.0213	.057		.35	.017	.0113	-.003
	-3.38	-.210	.0167	.025		-4.30	-.291	.0290	.076		.89	.042	.0118	-.010
	-4.47	-.287	.0259	.036		.08	0	.0098	0		1.95	.091	.0146	-.023
	.03	-.003	.0062	.001		.36	.021	.0100	-.005		2.99	.139	.0192	-.035
	.20	.016	.0063	0		.90	.055	.0106	-.013		4.04	.186	.0248	-.047
	.75	.048	.0070	-.004		1.96	.121	.0141	-.030		6.13	.281	.0404	-.071
	2.03	.112	.0096	-.012		3.02	.192	.0193	-.049		8.22	.372	.0621	-.093
	3.04	.182	.0138	-.021		4.08	.265	.0265	-.068		10.30	.457	.0894	-.114
	4.13	.256	.0213	-.032		6.20	.408	.0482	-.106		12.39	.540	.1225	-.134
	6.32	.405	.0450	-.050		8.32	.547	.0806	-.143		14.48	.618	.1605	-.150
	8.50	.542	.0806	-.054	1.30	-.31	-.026	.0113	.007		16.57	.690	.2040	-.160
	10.64	.650	.1215	-.055		-.58	-.040	.0118	.010	1.90	-.30	-.017	.0131	.005
	12.80	.772	.1740	-.062		-1.12	-.072	.0130	.018		-.57	-.028	.0134	.008
	15.01	.863	.2287	-.060		-2.18	-.133	.0169	.034		-1.10	-.050	.0140	.013
	17.12	.945	.2875	-.068		-3.23	-.199	.0224	.052		-2.14	-.094	.0164	.024
	18.17	.979	.3176	-.069		-4.29	-.266	.0298	.070		-3.18	-.136	.0203	.034
0.80	-.37	-.030	.0060	.003		.08	.002	.0114	0		-4.22	-.178	.0256	.045
	-.64	-.045	.0066	.005		.36	.019	.0114	-.004		.08	.002	.0130	0
	-1.20	-.078	.0079	.009		.90	.050	.0119	-.012		.35	.014	.0131	-.003
	-2.29	-.147	.0109	.017		1.96	.113	.0152	-.028		.88	.036	.0136	-.009
	-3.41	-.223	.0173	.029		3.01	.177	.0204	-.045		1.93	.080	.0157	-.020
	-4.51	-.304	.0266	.041		4.07	.242	.0272	-.063		2.97	.122	.0192	-.030
	.02	-.002	.0059	.001		6.18	.371	.0474	-.098		4.01	.165	.0241	-.041
	.31	.019	.0061	-.001		8.29	.494	.0757	-.131		6.09	.248	.0378	-.061
	.86	.052	.0068	-.005		10.39	.601	.1111	-.154		8.16	.327	.0567	-.080
	1.96	.120	.0095	-.014		12.49	.703	.1546	-.173		10.24	.405	.0813	-.097
	3.06	.193	.0148	-.024	1.50	-.31	-.022	.0114	.006		12.32	.479	.1107	-.114
	4.15	.273	.0233	-.037		-.58	-.036	.0117	.010		14.39	.557	.1470	-.131
	6.37	.425	.0483	-.057		-1.11	-.063	.0124	.017		16.49	.626	.1866	-.141
	8.55	.559	.0837	-.060							17.54	.661	.2095	-.147
	10.72	.677	.1273	-.071										
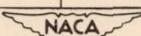
TABLE II.- AERODYNAMIC CHARACTERISTICS OF WING
WITH TAPER RATIO OF 0.2 - Concluded
(b) R = 4.0 million per foot

M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.60	-0.45	-0.030	0.0073	0.003	0.70	-1.23	-0.079	0.0087	0.008	0.80	0.32	0.020	0.0065	-0.002
	-.66	-.045	.0076	.005		-2.32	-.142	.0115	.015		.89	.057	.0073	-.006
	-1.21	-.076	.0088	.008		-3.44	-.208	.0169	.024		2.01	.125	.0100	-.014
	-2.30	-.136	.0113	.014		-4.55	-.288	.0261	.035		3.11	.194	.0147	-.024
	-3.39	-.205	.0165	.022		.02	-.006	.0065	.001		4.24	.269	.0225	-.035
	-4.48	-.273	.0246	.031		.31	.016	.0068	-.001		6.47	.424	.0485	-.055
	.02	-.006	.0068	0		.88	.052	.0074	-.005		8.70	.557	.0848	-.060
	.31	.016	.0069	-.001		1.98	.115	.0101	-.012		10.90	.673	.1286	-.069
	.87	.048	.0075	-.004		3.08	.181	.0141	-.021		13.09	.784	.1803	-.077
	1.96	.110	.0100	-.011		4.18	.253	.0212	-.031					
	3.05	.174	.0136	-.019		6.40	.402	.0452	-.049	0.90	-.40	-.032	.0066	.004
	4.14	.246	.0207	-.029		8.62	.538	.0814	-.055		-.69	-.050	.0072	.006
	6.33	.387	.0428	-.045		10.79	.641	.1208	-.053		-1.25	-.087	.0086	.011
	8.53	.520	.0775	-.052		12.99	.765	.1726	-.060		-2.38	-.161	.0123	.022
	10.69	.630	.1171	-.049		15.21	.856	.2280	-.058		-3.50	-.237	.0190	.035
	12.88	.759	.1689	-.054							-4.64	-.327	.0304	.050
	15.10	.854	.2238	-.055	0.80	-.48	-.031	.0068	.004		.02	-.002	.0061	.001
	17.24	.940	.2825	-.054		-.67	-.047	.0073	.005		.33	.023	.0062	-.002
	18.28	.972	.3114	-.053		-2.34	-.082	.0086	.009		.91	.060	.0071	-.007
						-3.46	-.225	.0182	.029		2.03	.135	.0102	-.018
0.70	-.39	-.031	.0070	.003		-4.58	-.302	.0278	.041		3.16	.216	.0154	-.031
	-.67	-.046	.0075	.005		.02	-.003	.0063	.001		4.29	.296	.0242	-.045
											6.58	.469	.0544	-.071

(c) R = 6.0 million per foot

| M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.80	-0.50	-0.036	0.0076	0.003	0.90	-0.43	-0.035	0.0075	0.003
	-.72	-.051	.0078	.005		-.73	-.055	.0082	.006
	-1.29	-.083	.0087	.008		-1.31	-.091	.0092	.011
	-2.42	-.146	.0135	.015		-2.48	-.163	.0122	.020
	-3.59	-.226	.0133	.026		-3.65	-.240	.0187	.031
	-4.74	-.294	.0260	.035		-4.85	-.331	.0300	.046
	.02	-.001	.0071	0		.02	-.002	.0072	0
	.35	.025	.0072	-.003		.35	.026	.0073	-.003
	.93	.057	.0078	-.006		.95	.065	.0082	-.008
	2.07	.125	.0100	-.014		2.09	.131	.0105	-.017
	3.21	.191	.0138	-.023		3.29	.219	.0156	-.031
	4.36	.263	.0211	-.032		4.46	.297	.0241	-.043
	6.69	.418	.0481	-.052		6.84	.463	.0548	-.065
	8.95	.533	.0804	-.060					

NACA
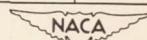
TABLE III.- AERODYNAMIC CHARACTERISTICS OF WING WITH TAPER RATIO OF 0.4
(a) R = 3.0 million per foot

| M	α	C_L	C_D	C_m	M	α	C_L	C_D	C_m	M	α	C_L	C_D	C_m
0.60	-0.41	-0.023	0.0078	0	0.80	12.86	0.762	0.1719	-0.050	1.50	-2.15	-0.113	0.0153	0.026
	-.68	-.037	.0084	0		14.99	.841	.2217	-.040		-3.20	-.172	.0203	.041
	-1.23	-.068	.0091	.002		17.08	.903	.2735	-.037		-4.25	-.227	.0267	.056
	-2.23	-.125	.0112	.005		18.13	.931	.3002	-.038		.07	.006	.0109	-.002
	-3.31	-.192	.0163	.009							.34	.021	.0110	-.005
	-4.37	-.264	.0242	.019	0.90	-.42	-.024	.0070	0		.89	.050	.0117	-.011
	.04	.002	.0070	-.001		-.69	-.041	.0077	.001		1.95	.103	.0146	-.024
	.31	.018	.0074	-.002		-1.19	-.077	.0084	.005		2.99	.160	.0192	-.038
	.86	.047	.0085	-.003		-2.29	-.148	.0115	.010		4.04	.215	.0255	-.053
	1.95	.108	.0106	-.007		-3.40	-.228	.0185	.021		6.24	.322	.0429	-.082
	3.01	.169	.0149	-.011		-4.50	-.316	.0291	.038		8.22	.422	.0661	-.108
	4.10	.241	.0221	-.019		.05	.007	.0062	-.001		10.31	.519	.0958	-.130
	6.26	.385	.0444	-.038		.33	.024	.0066	-.001		12.40	.606	.1309	-.146
	8.43	.532	.0785	-.053		.89	.060	.0076	-.005		14.48	.682	.1718	-.155
	10.58	.642	.1189	-.039		2.00	.133	.0099	-.012		16.58	.757	.2198	-.168
	12.71	.740	.1630	-.034		3.10	.210	.0158	-.021					
	14.83	.833	.2138	-.026		4.21	.294	.0252	-.037	1.70	-.30	-.017	.0110	.004
	16.96	.925	.2734	-.019		6.45	.473	.0541	-.067		-.55	-.030	.0112	.006
	18.00	.956	.3014	-.014		8.64	.612	.0921	-.078		-1.09	-.053	.0122	.012
0.70	-.42	-.022	.0078	0	1.20	-.31	-.024	.0098	.005		-2.14	-.102	.0151	.024
	-.69	-.037	.0085	0		-.57	-.038	.0105	.008		-3.18	-.153	.0198	.037
	-1.24	-.066	.0092	.003		-1.11	-.068	.0115	.014		-4.22	-.201	.0258	.049
	-2.25	-.130	.0113	.006		-2.17	-.135	.0146	.027		.08	.007	.0107	-.002
	-3.28	-.197	.0165	.010		-3.23	-.204	.0195	.041		.35	.018	.0109	-.005
	-4.42	-.274	.0249	.021		-4.29	-.272	.0269	.056		.88	.043	.0115	-.011
	.04	.004	.0071	-.001		.08	.006	.0093	-.002		1.93	.093	.0141	-.023
	.32	.019	.0075	-.001		.36	.025	.0097	-.005		2.97	.143	.0185	-.035
	.87	.049	.0085	-.003		.90	.058	.0110	-.012		4.01	.190	.0243	-.047
	1.95	.112	.0106	-.007		1.96	.122	.0139	-.025		6.10	.284	.0396	-.071
	3.04	.178	.0153	-.012		3.01	.189	.0185	-.039		8.18	.373	.0606	-.092
	4.13	.250	.0228	-.021		4.08	.257	.0254	-.053		10.25	.456	.0867	-.112
	6.31	.403	.0461	-.042		6.19	.395	.0470	-.088		12.33	.538	.1187	-.129
	8.50	.554	.0825	-.057		8.30	.520	.0763	-.117		14.41	.614	.1553	-.142
	10.64	.641	.1197	-.038	1.30	-.30	-.021	.0113	.004		16.48	.682	.1966	-.148
	12.78	.750	.1673	-.036		-.57	-.036	.0118	.007		17.53	.716	.2212	-.152
	14.92	.840	.2179	-.031		-1.11	-.065	.0129	.014					
	17.03	.923	.2756	-.025		-2.16	-.128	.0159	.027	1.90	-.30	-.018	.0125	.004
	18.08	.954	.3041	-.022		-3.20	-.192	.0208	.042		-.55	-.029	.0127	.006
0.80	-.42	-.022	.0077	-.001		-4.27	-.255	.0280	.057		-1.09	-.052	.0133	.012
	-.69	-.037	.0082	0		.08	.006	.0109	-.002		-2.13	-.096	.0158	.023
	-1.25	-.067	.0088	.003		.36	.023	.0112	-.005		-3.17	-.140	.0198	.033
	-2.26	-.130	.0110	.006		.89	.054	.0123	-.011		-4.21	-.183	.0253	.043
	-3.36	-.199	.0165	.012		1.96	.113	.0152	-.024		.07	.003	.0121	-.001
	-4.45	-.280	.0255	.026		3.01	.177	.0197	-.039		.34	.014	.0122	-.004
	.06	.005	.0069	-.001		4.07	.240	.0264	-.055		.87	.037	.0127	-.010
	.39	.021	.0073	-.001		6.27	.366	.0458	-.087		1.92	.082	.0148	-.020
	.88	.053	.0082	-.003		8.34	.480	.0726	-.116		2.96	.126	.0183	-.031
	1.98	.118	.0102	-.008		10.36	.584	.1065	-.135		3.99	.169	.0234	-.041
	3.06	.185	.0151	-.014		12.47	.682	.1469	-.151		6.06	.250	.0371	-.060
	4.16	.261	.0232	-.025							8.13	.332	.0562	-.079
	6.37	.471	.0477	-.048	1.50	-.30	-.019	.0111	.004		10.21	.410	.0802	-.096
	8.55	.555	.0832	-.056		-.56	-.033	.0115	.007		12.27	.479	.1080	-.111
	10.69	.642	.1205	-.042		-1.11	-.059	.0124	.013		14.34	.549	.1415	-.123
											16.41	.614	.1789	-.130
											17.45	.649	.2008	-.134
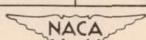
TABLE III.- AERODYNAMIC CHARACTERISTICS OF WING
WITH TAPER RATIO OF 0.4 - Concluded
(b) R = 4.0 million per foot

M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.70	-0.39	-0.022	0.0075	-0.001	0.60	-1.25	-0.065	0.0084	0.001	0.80	0.08	0.006	0.0066	-0.001
	-.68	-.039	.0076	0		-2.34	-.128	.0114	.004		.36	.022	.0070	-.001
	-1.24	-.069	.0082	.001		-3.34	-.188	.0158	.008		.93	.055	.0078	-.003
	-2.25	-.131	.0112	.005		-4.43	-.258	.0231	.014		2.03	.117	.0100	-.008
	-3.35	-.196	.0160	.009		.04	.004	.0069	-.001		3.14	.188	.0150	-.013
	-4.45	-.267	.0238	.017		.35	.020	.0074	-.001		4.26	.262	.0228	-.023
	.07	.005	.0069	-.001		.88	.051	.0082	-.002		6.49	.416	.0474	-.044
	.36	.020	.0072	-.001		1.97	.112	.0107	-.006		8.73	.563	.0845	-.052
	.92	.053	.0082	-.003		3.06	.175	.0151	-.010		10.92	.659	.1252	-.041
	2.01	.115	.0105	-.007		4.14	.238	.0215	-.015		13.11	.785	.1803	-.050
	3.12	.179	.0154	-.011		6.35	.394	.0446	-.036					
	4.22	.248	.0225	-.017		8.52	.533	.0786	-.050	0.90	-.40	-.024	.0070	-.001
	6.44	.400	.0448	-.038		10.71	.645	.1178	-.038		-.69	-.041	.0075	0
	8.67	.551	.0817	-.053		12.87	.757	.1657	-.032		-1.26	-.076	.0081	.003
	10.83	.651	.1204	-.037		15.02	.852	.2182	-.023		-2.30	-.147	.0118	.009
	13.01	.760	.1691	-.033		17.17	.945	.2793	-.017		-3.43	-.222	.0180	.018
	15.19	.858	.2229	-.028		18.31	.979	.3101	-.013		-4.38	-.308	.0276	.031
											2.06	.131	.0097	-.010
0.60	-.42	-.022	.0075	-.001	0.80	-3.37	-.206	.0159	.012		3.18	.206	.0160	-.018
	-.69	-.036	.0080	0		-4.49	-.277	.0240	.020		4.32	.286	.0245	-.032
											6.60	.462	.0535	-.062

(c) R = 6.0 million per foot

| M	α	c_L	c_D	c_m	M	α	c_L	c_D	c_m
0.80	-0.48	-0.028	0.0081	0	0.90	-0.47	-0.030	0.0078	0
	-.75	-.045	.0080	.001		-.77	-.046	.0079	.001
	-1.32	-.075	.0087	.002		-1.34	-.080	.0090	.003
	-2.39	-.140	.0113	.005		-2.44	-.154	.0120	.009
	-3.51	-.201	.0160	.009		-3.61	-.231	.0182	.017
	-4.68	-.281	.0246	.019		-4.78	-.311	.0277	.030
	.05	.008	.0076	-.001		.07	.010	.0075	-.002
	.35	.026	.0078	-.002		.37	.028	.0078	-.002
	.94	.059	.0083	-.003		.95	.063	.0086	-.005
	2.08	.122	.0105	-.007		2.09	.129	.0108	-.009
	3.22	.190	.0152	-.011		3.27	.206	.0157	-.016
	4.36	.258	.0221	-.017		4.46	.285	.0243	-.028
	6.67	.407	.0473	-.041		6.78	.435	.0498	-.051
	8.48	.535	.0743	-.051					

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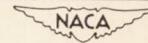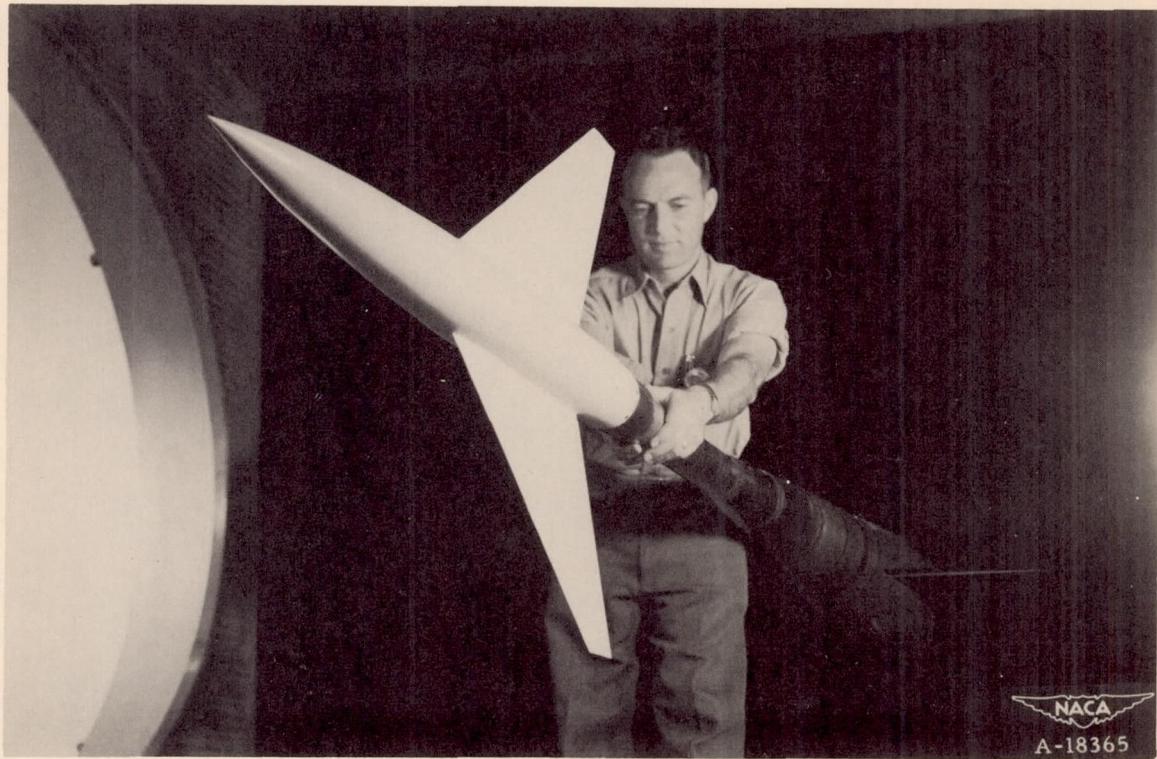
Figure 1.- Model with wing of taper ratio of 0.2 installed in Ames
6- by 6-foot supersonic wind tunnel.
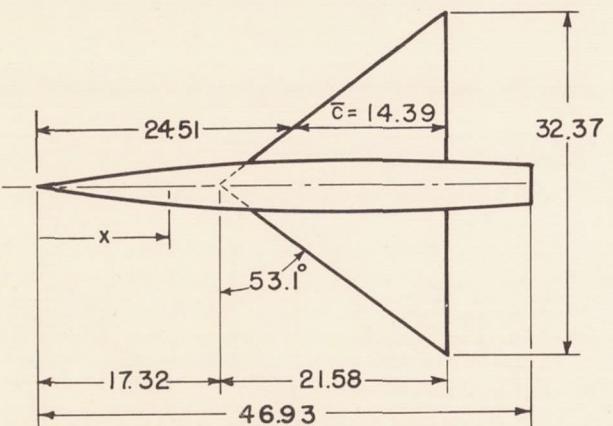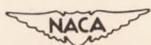
(a) Taper ratio = 0.
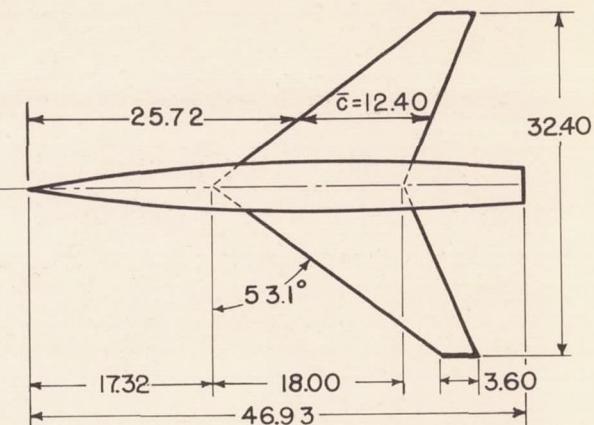
(b) Taper ratio = 0.2.
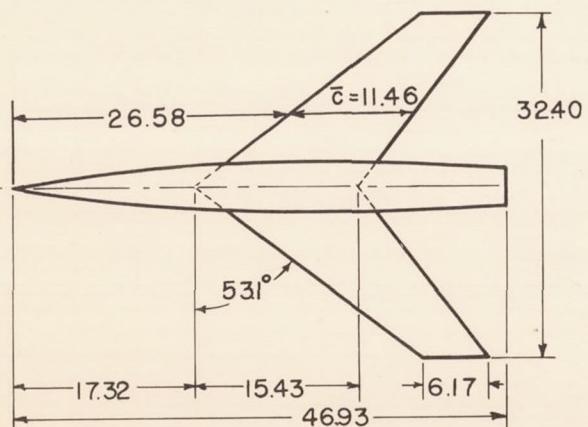
Equation for body radius:

$$r = r_o \left[1 - \left(1 - \frac{2x}{\int} \right)^2 \right]^{3/4}$$

Maximum radius, $r_o = 2.38$

Length for closure, $\int = 59.50$

(c) Taper ratio = 0.4.

All dimensions in inches unless otherwise noted

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Figure 2.- Dimensional sketches of models.
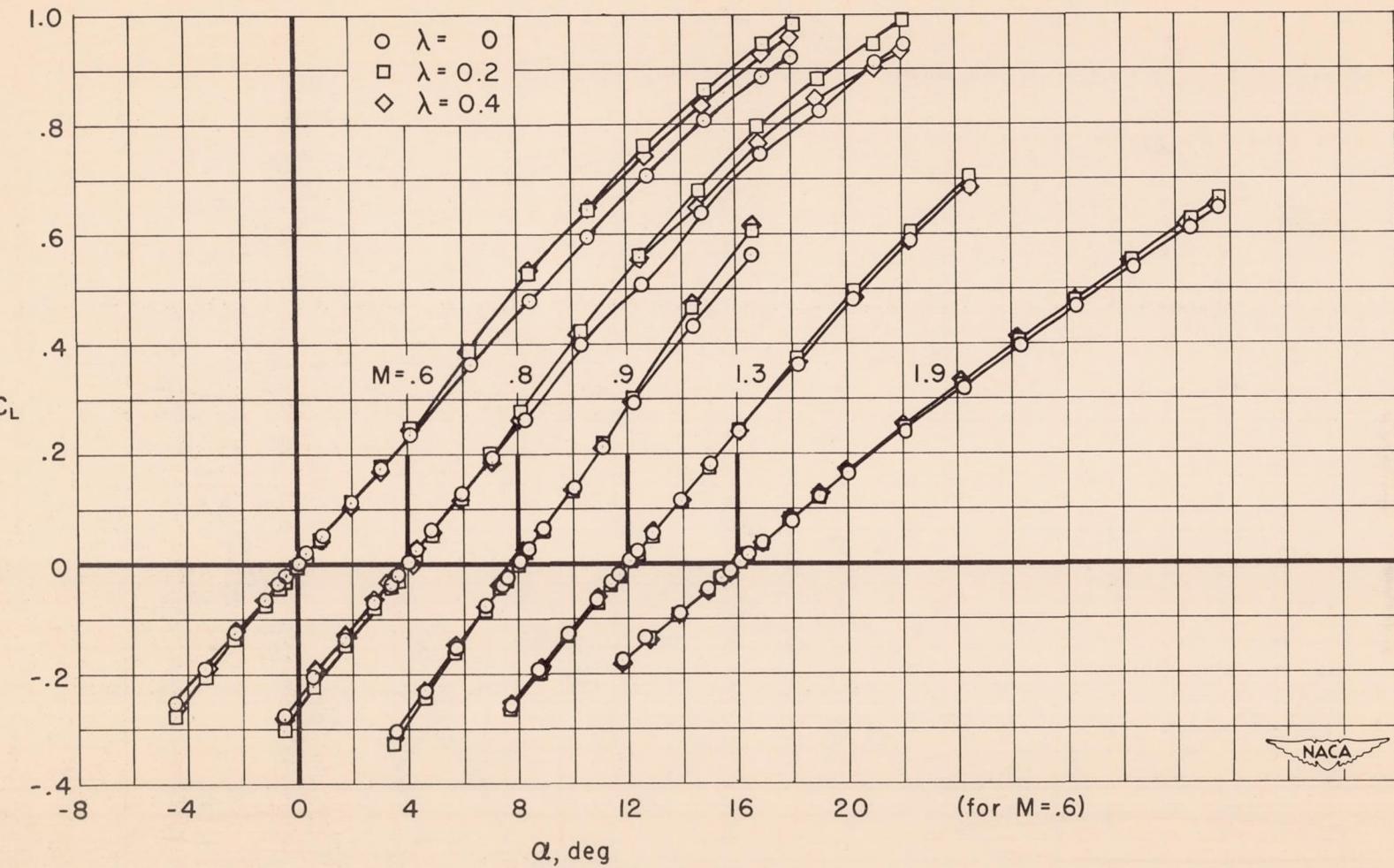
Figure 3.- Effect of taper ratio on the variation of lift coefficient with angle of attack; R = 3.0 million per foot.
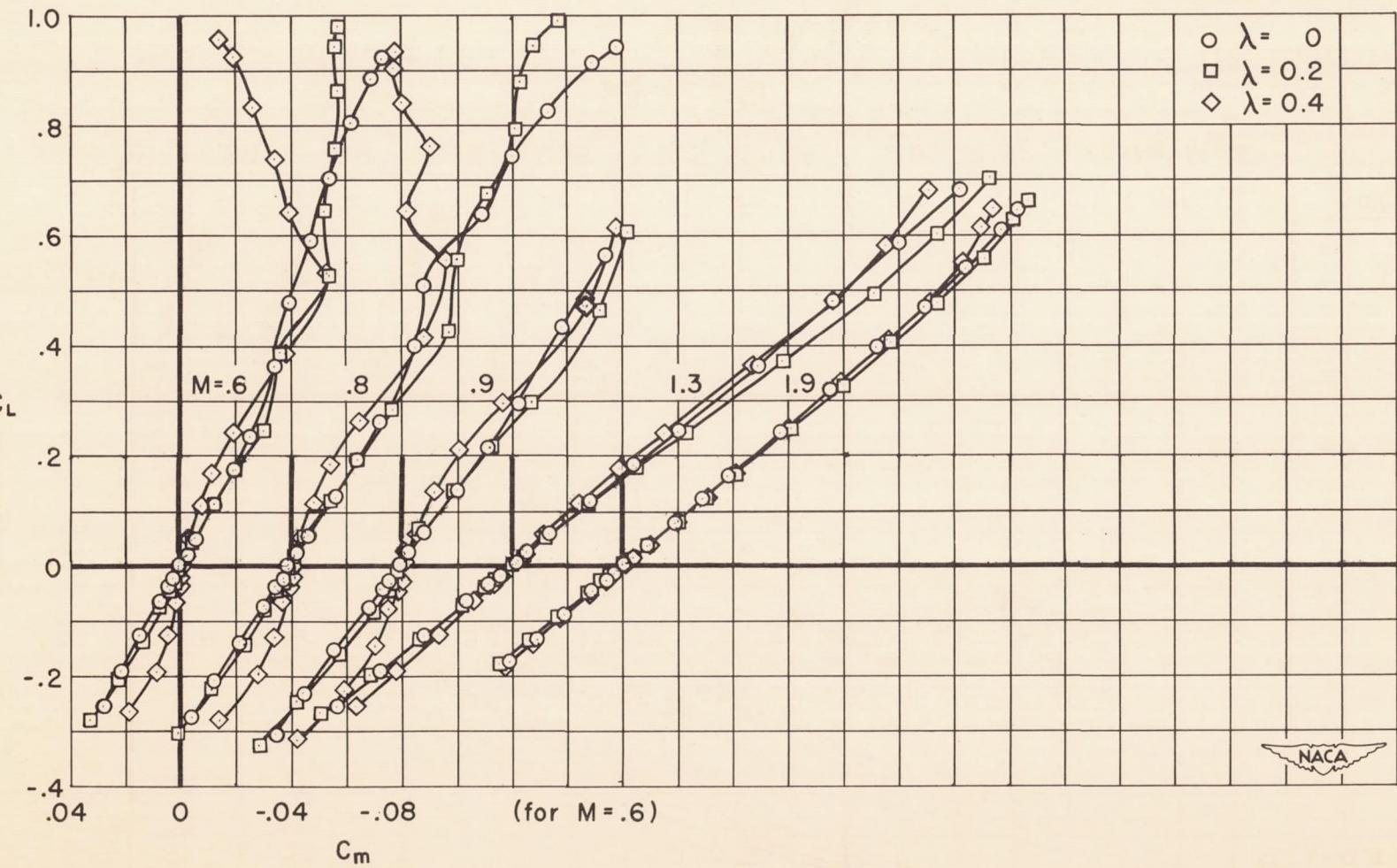
Figure 4.- Effect of taper ratio on the variation of pitching-moment coefficient with lift coefficient; R = 3.0 million per foot.
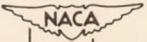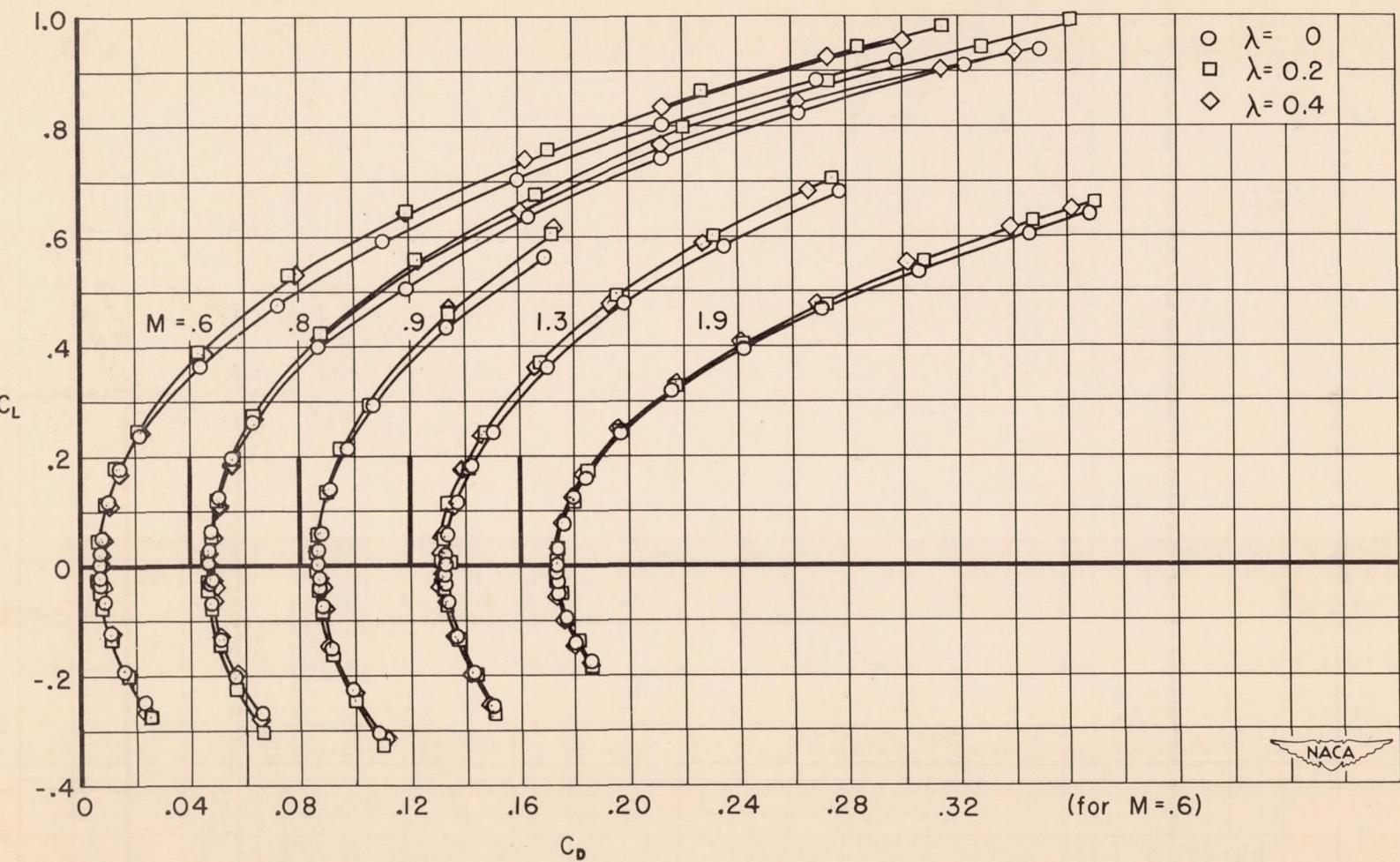
Figure 5.- Effect of taper ratio on the variation of drag coefficient with lift coefficient;
R = 3.0 million per foot.
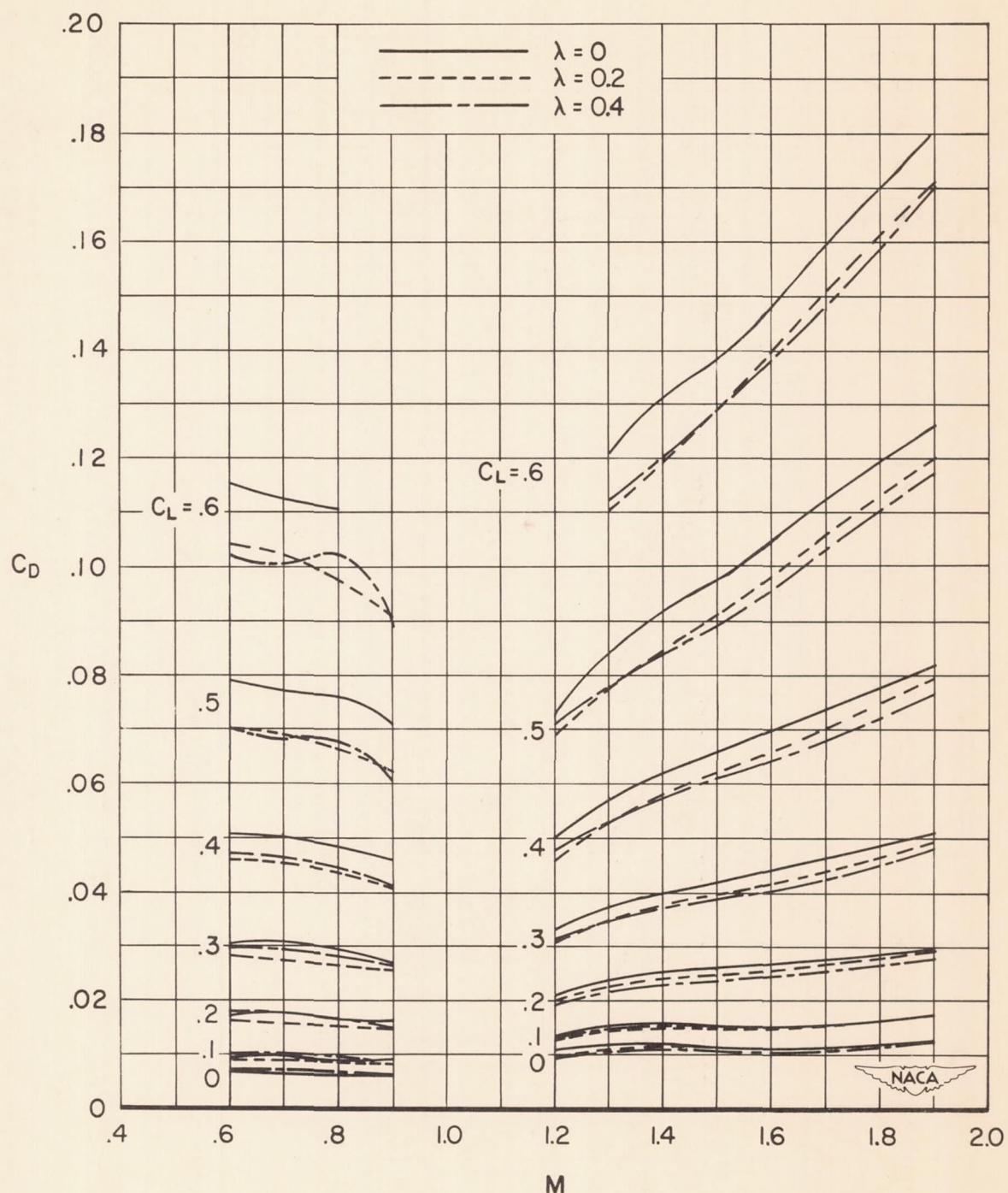
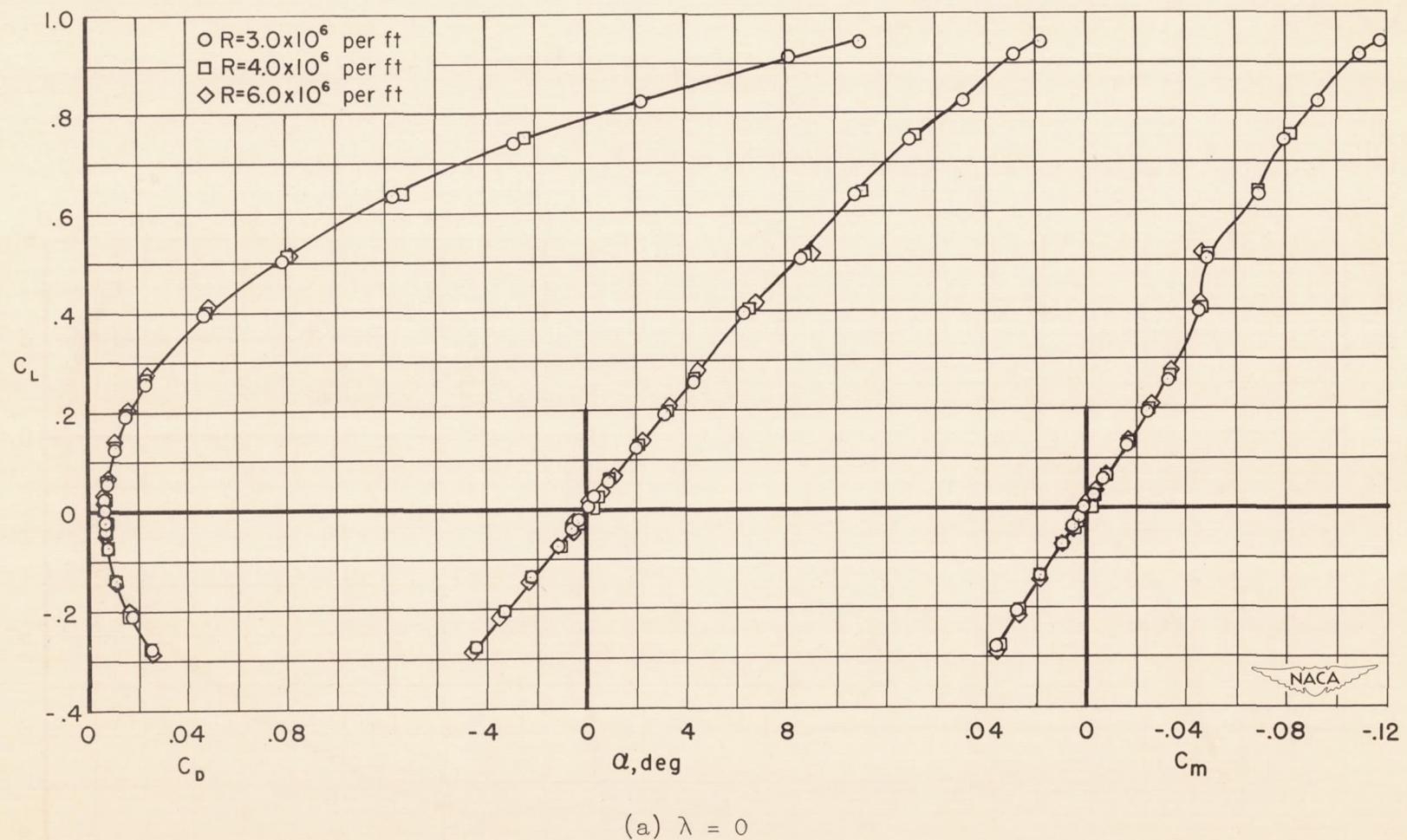Figure 6.- Effect of taper ratio on the variation with Mach number of the drag coefficients at various lift coefficients; R = 3.0 million per foot.
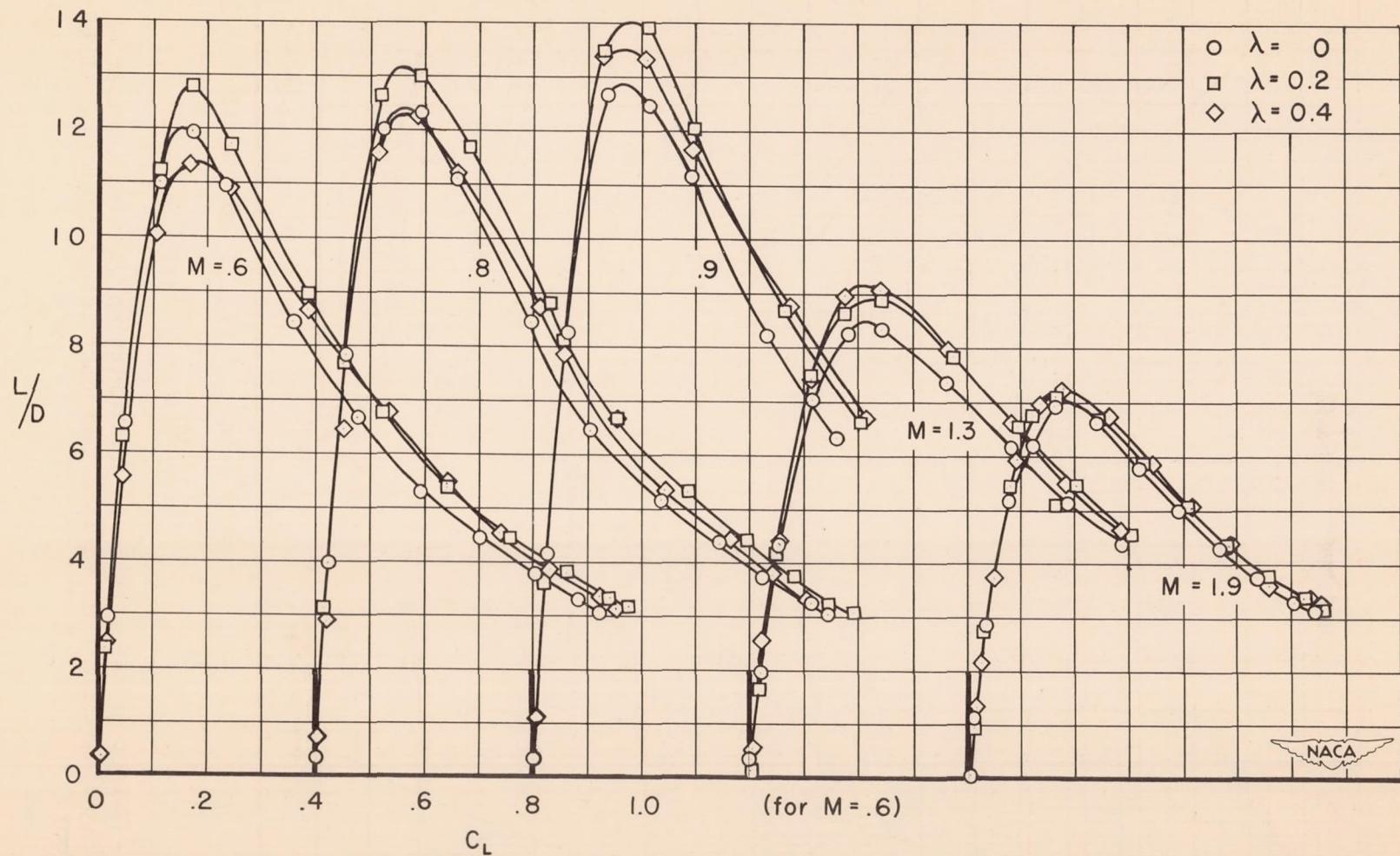
Figure 7.- Effect of taper ratio on the variation of lift-drag ratio with lift coefficient; R = 3.0 million per foot.

(a) $\lambda = 0$

Figure 8.- Effect of Reynolds number on aerodynamic characteristics of the three models at a Mach number of 0.8.

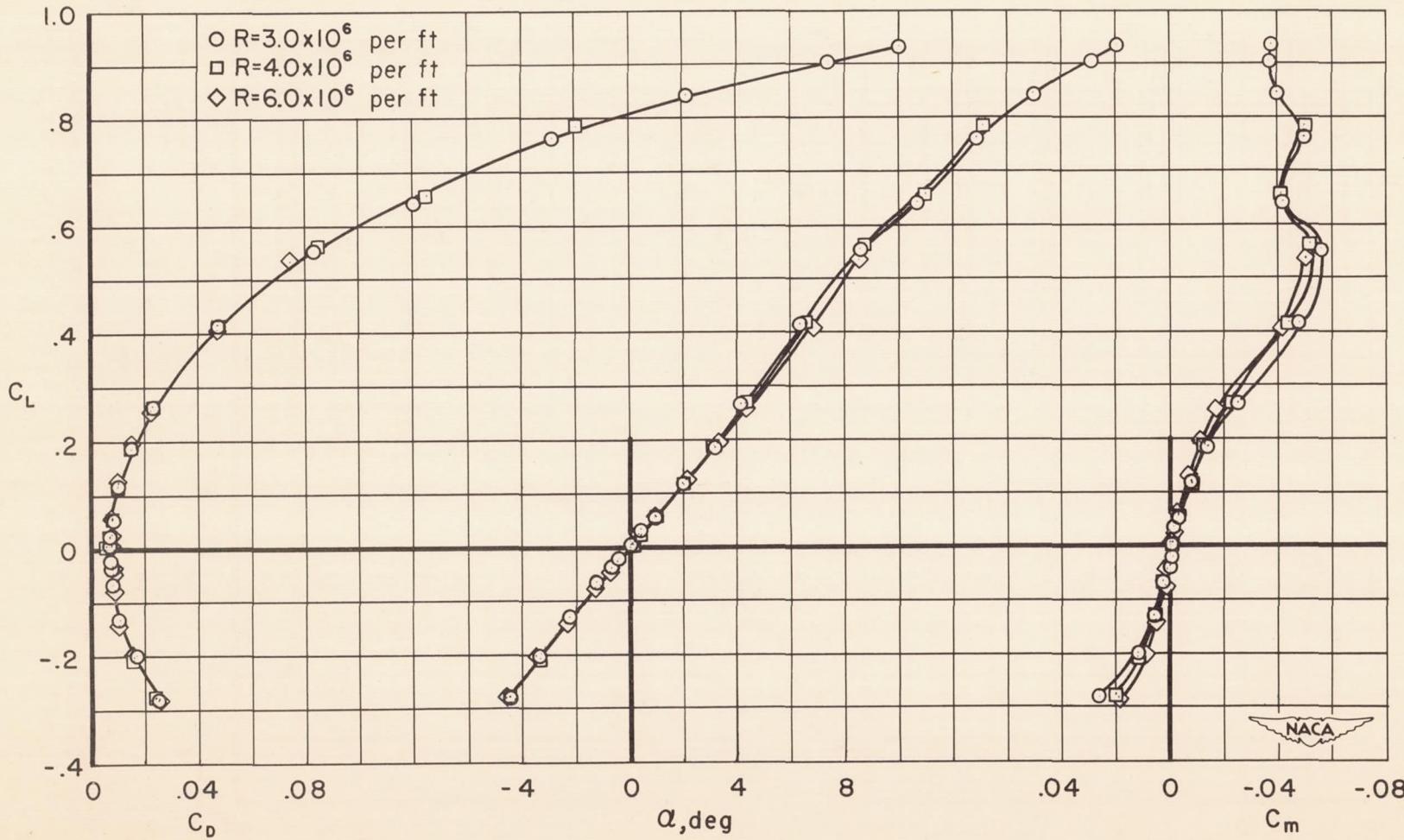O R=3.0x10⁶ per ft
□ R=4.0x10⁶ per ft
◇ R=6.0x10⁶ per ft

(b) λ = 0.2
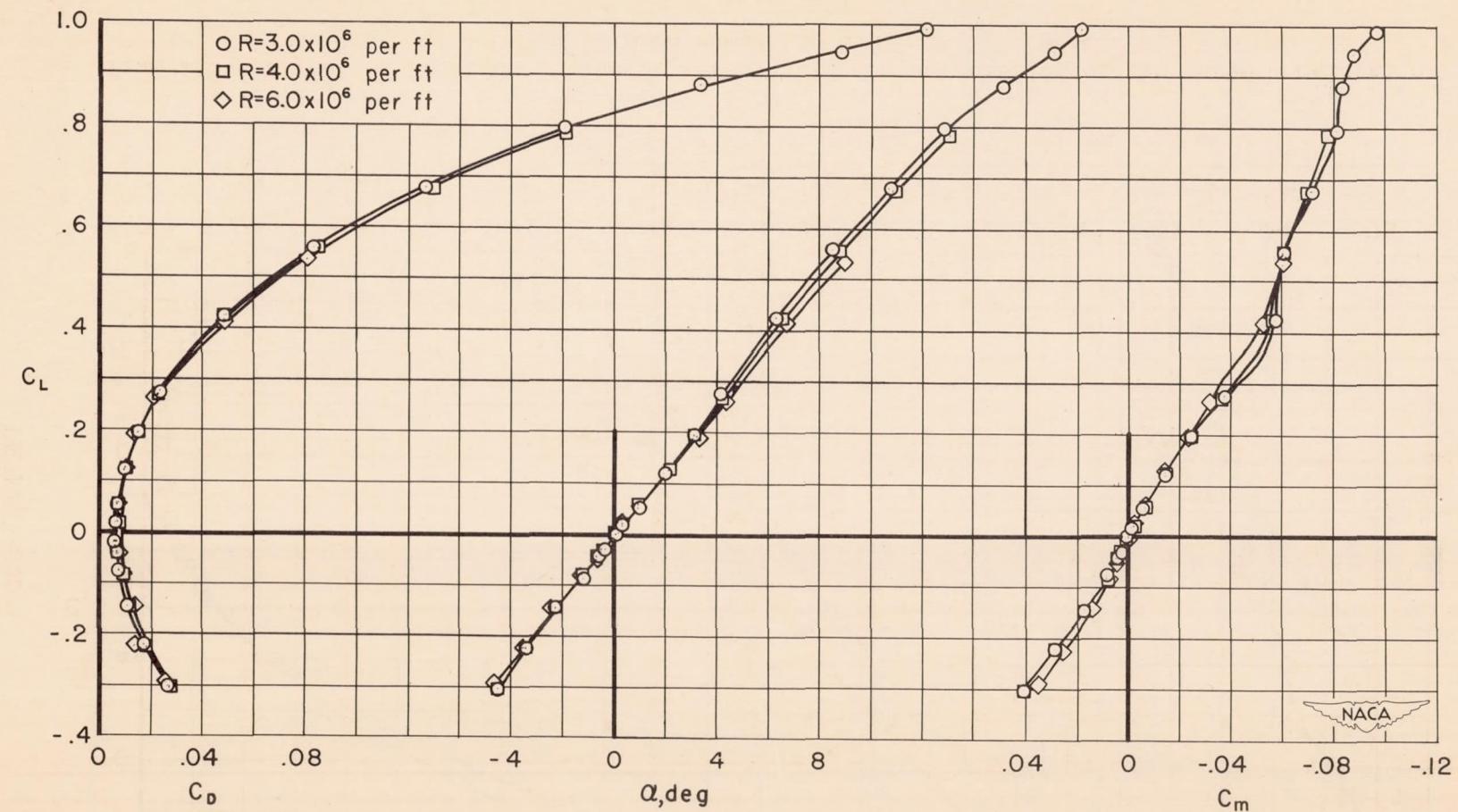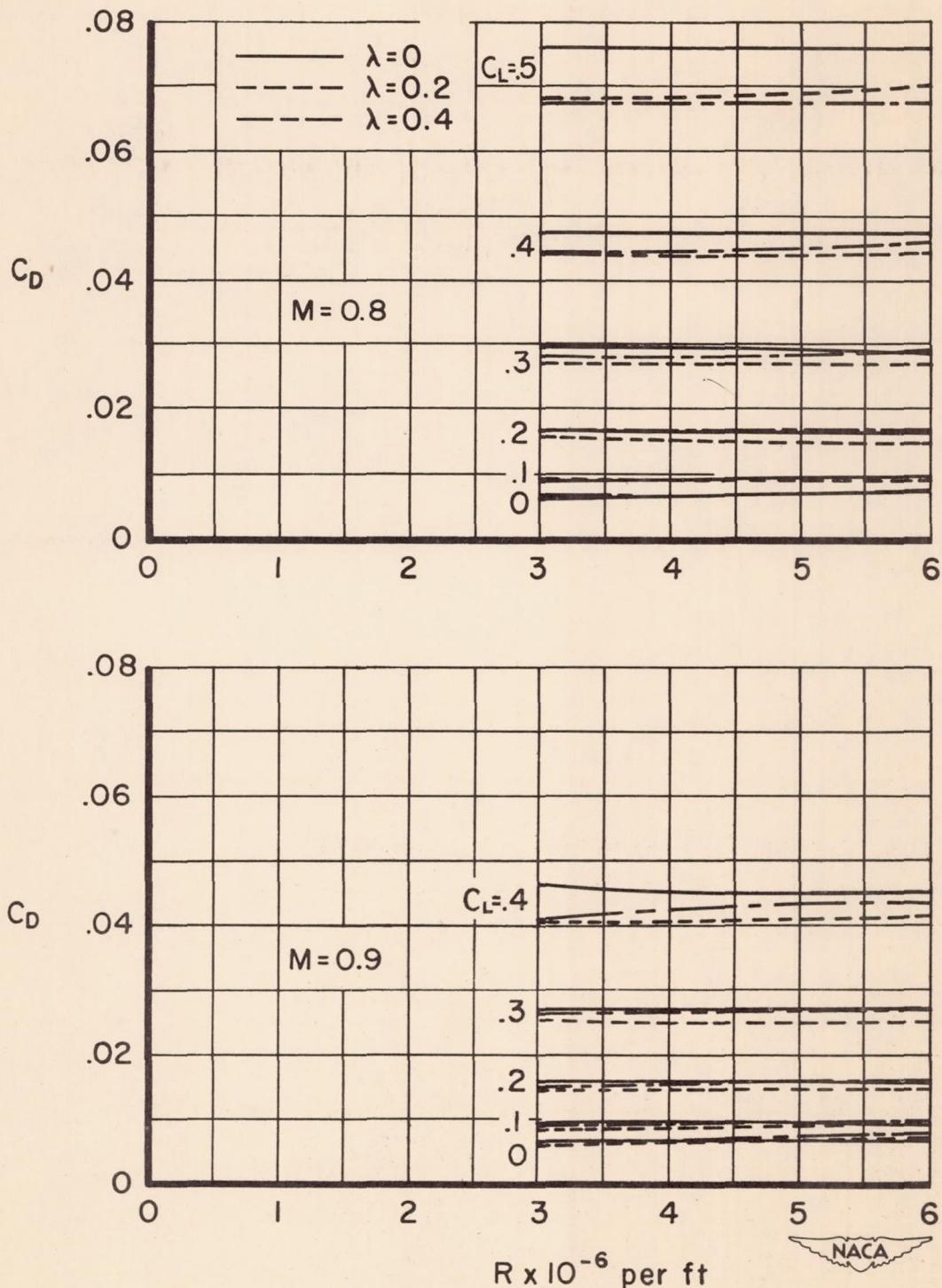
Figure 8.- Continued.

(c) $\lambda = 0.4$

Figure 8.- Concluded.

Figure 9.- Variation with Reynolds number of the drag coefficients at various lift coefficients for the three models at subsonic speeds.